EXTENDING WOOD AND ENERGY SUPPLY
THROUGH FOREST PRODUCTS RESEARCH

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Summary

Advances in wood utilization technology promise to extend timber and energy supplies. In addition to more effectively using current supplies, research will help conserve energy by capitalizing on the inherent advantages of wood as an engineering and raw material.

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The capability and creativity of the wood scientist are being tested in the United States today as they have never been tested before. There are several reasons for this. Outstanding among them are:

1. Wood is a leading industrial and engineering material.

2. Timber supply is increasing, but often not in the sizes, species, and locations most commonly wanted by timber processors.

3. Demand for timber continues strong and is projected to increase.

As a consequence, we face the challenge of matching new technology with a changing--and expanding--timber resource to satisfy a growing economy that demands more wood products and much, much more wood energy. Here is a unique opportunity for the wood scientist to prove his mettle. Several new options in forest products utilization have come from the research inspired by this situation. In this paper, I will describe the situation of timber supply and demand in the United States and some of the utilization options that are emerging to help cope with it.

1/ The Forest Products Laboratory is maintained at Madison, Wis., in cooperation with the University of Wisconsin.

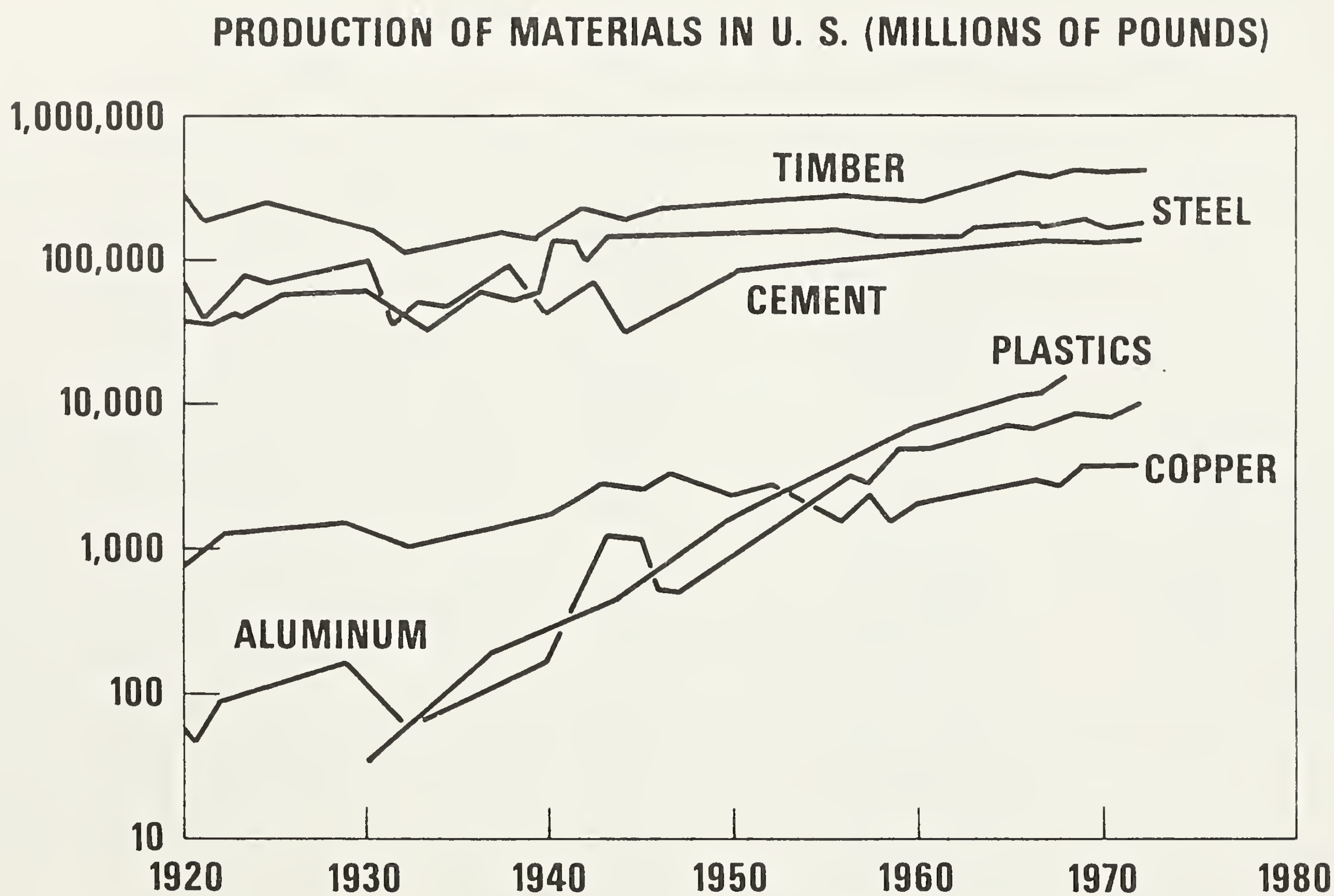

Figure 1.--Materials produced in the United States, 1920-1972, in millions of pounds of product.

(M 143 118)

However, before I do that, let me explain why I think this question has broader significance than its primary focus on the U.S. situation would immediately imply. There are parallels with other nations. First, the basic approaches to problem solution are through more efficient use of currently available timber, and devising effective, economical uses for timber not now being used. While other nations' timber situation may differ markedly in some ways from that of the United States, many nations (especially developing nations of the tropics and subtropics) do have large quantities of timber available in the "secondary" or underutilized species, together with a much smaller number of species that are overcut in accessible areas.

Second, and following from the first, technology in effect changes the resource to the extent that it can be applied to that resource. Improved technology has made possible the spread of the plywood and lumber industries and the expansion in scope of the particleboard industry in the United States by making it possible to use portions of the timber resource not previously considered economically useable; technology can do the same, with some variations, in other nations where it can be applied.

Third. Just as interest in use of renewable resources for materials and energy is a fact of life in developing nations, (to the extent that their economic and social conditions provide for applying emerging technology), so do we in the United States face a new awareness of such possibilities. We are looking back to earlier days with today's technology. Perhaps we are approaching the same situation from different directions.

Wood Is a Leading Industrial and Engineering Material

Production of forest products for industrial and engineering use in the United States has been about 200 million tons per year for the last several years. This exceeds the combined production of cement, plastics, and metals (figs. 1 and 2) now, even though production of plastics, in particular, has been escalating rapidly in recent years.

In earlier years, our country ran on wood. Forests provided essentially all of the fuel and most of the raw material required for a rapidly expanding economy. Fortunately, our alternatives have increased since that time. Today, increasing numbers of people are concerned about the outlook for energy and materials. We have had one recent oil embargo and rapid escalation of oil prices. We are similarly vulnerable to restrictions on supplies of strategic minerals and metals. Many of us are beginning to ponder seriously the question "What is the future place of wood in this rapidly changing world?" We cannot be sure, but there are clear indications that wood will play an increasingly important role.

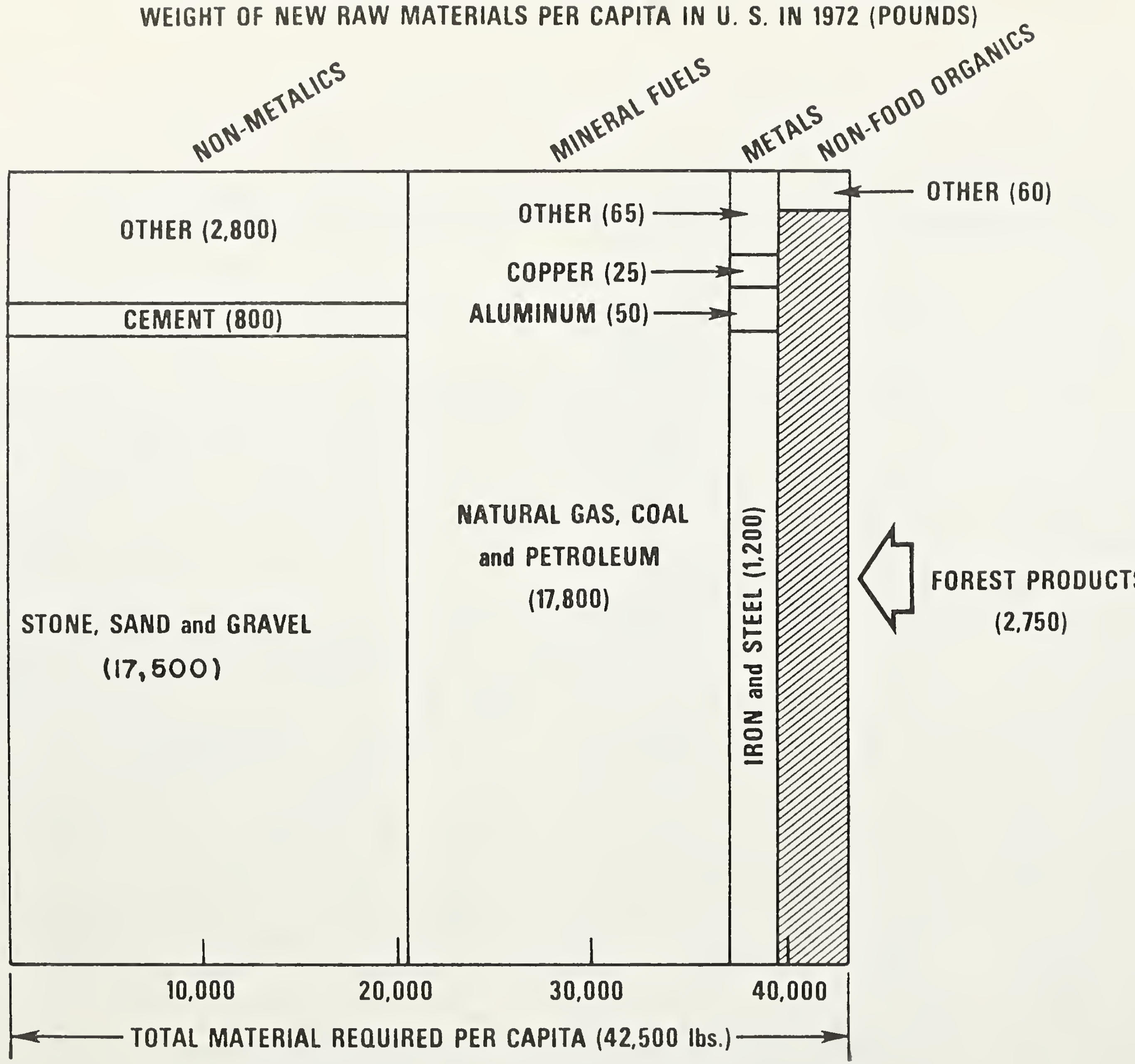

Figure 2.--Weight (in pounds) of new raw materials produced in the United States, per capita, in 1972.

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Timber Supply Is Increasing

A. The United States is blessed with a rich, renewable, and expandable forest resource.

My chief basis for this statement is the array of data contained in the most recent timber inventory report "Forest Statistics of the U.S., 1977," as well as material gathered for the 1980 Resources Planning Act Assessment.3/

About 202 million hectares (500 million acres)--some 22 percent of the Nation's land area--is commercial timberland capable of producing crops of timber and not withdrawn from timber harvest for other uses. The commercial timberlands of the United States contained more than 23 billion cubic meters (800 billion cubic feet) of timber in 1977. This equates to about 12 to 15 billion tons on a dry basis. However, some of our researchers have estimated that the above-ground "biomass"--wood, bark, foliage--on commercial forest land is probably two to three times as large as the measured timber volume. We think the total may be at least 25 billion tons on a dry basis.

B. Not only do we have abundant forests, but that abundance is increasing. Timber inventories in the United States have risen substantially over the past three decades.

This is not to say that everywhere we have excess supplies of low-cost timber of the highest quality and of the most desirable species and form. But let us look at some statistics from our latest timber inventory report. Comparing estimates for 1977 with those for 1952, we find that the United States has:

8 percent more softwood growing stock and

45 percent more hardwood growing stock.

These figures are for the main-stem volumes of trees of desirable species and acceptable quality--on the land we classify as "commercial forest."

Net volume in 1977 of timber of hardwoods and softwoods in several categories is shown in figure 3. Those volume figures indicate substantial volumes of rough and rotten hardwoods, and salvable dead trees (all potential raw material for many products or fuel) but the resource remains dominated by softwood sawtimber, our premier timber

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3/ The Forest and Rangeland Renewable Resources Planning Act of 1974 calls for the Secretary of Agriculture to prepare, each 10 years, an assessment of renewable resources on forests and associated rangelands of the United States. Latest publication is "An Assessment of the Forest and Range Land Situation in the United States. Forest Service, U.S. Department of Agriculture, F.S. 345. January 1980."

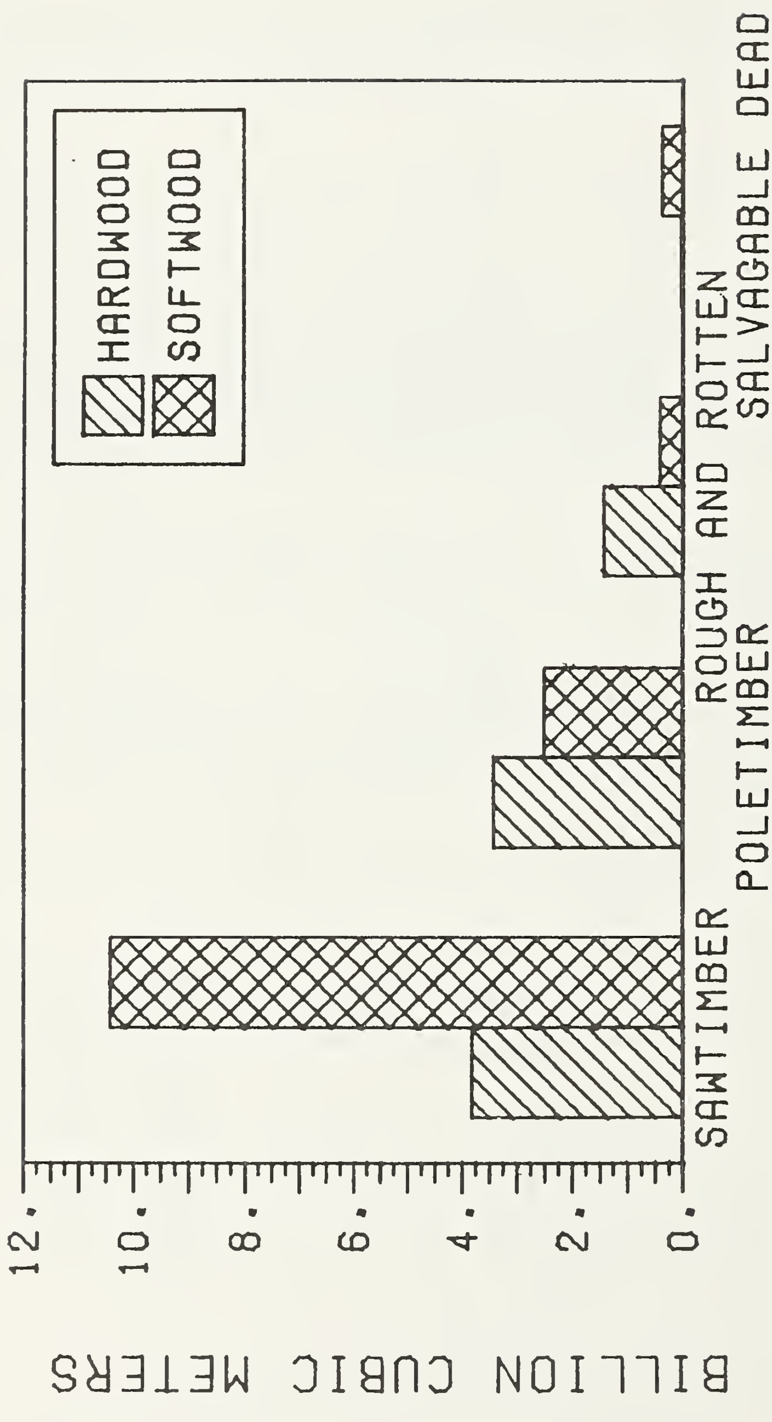

Figure 3.--Net volume of timber produced in the United States in 1977.

stock. Led by the South's "third" forest, U.S. timberlands are growing 50 percent more timber annually than 25 years ago (fig. 4).

Some 28 percent of the net growth is southern pine; another one-sixth is oak. Douglas-fir and other western conifers comprise another one-fifth of the annual growth.

Timber growth in the United States increased 225 thousand cubic meters in the last 25 years; however, timber harvest increased 73 thousand cubic meters.

C. The increase in timber inventory is due in part to declining per capita consumption of some major timber products.

Figure 5 shows the divergent trends in per capita consumption of roundwood during this century. Note that this is based on cubic meters per person. Let's untangle some of those trends:

The most significant decline has been in fuelwood, replaced by fossil fuels.

Miscellaneous products--including such things as cooperage, posts, and piling, and chemical wood--have declined also.

Lumber consumption on a per capita basis has declined.

Plywood and veneer consumption has trended upward, as has wood pulp. The upward trend in woodpulp consumption would appear more dramatic if it were expressed in terms of kilograms per capita rather than roundwood equivalent. This is because so much of U.S. pulp is manufactured from residues rather than from roundwood.

As a result of this declining per capita consumption of most categories of forest products, total consumption has not increased substantially except for wood pulp, even though population has increased considerably.

D. Demand for timber continues strong and is projected to increase.

Total consumption of forest products for the last 25 years, converted to metric tons of wood, is illustrated in figure 6.

We do anticipate marked increases in demand for some types of wood products (table 1). Note especially the projected increase in products that can use hardwoods, whole tree chips, low-quality timber resources, and recycled material:

Hardwood lumber

Wood pulp

Paper and boards

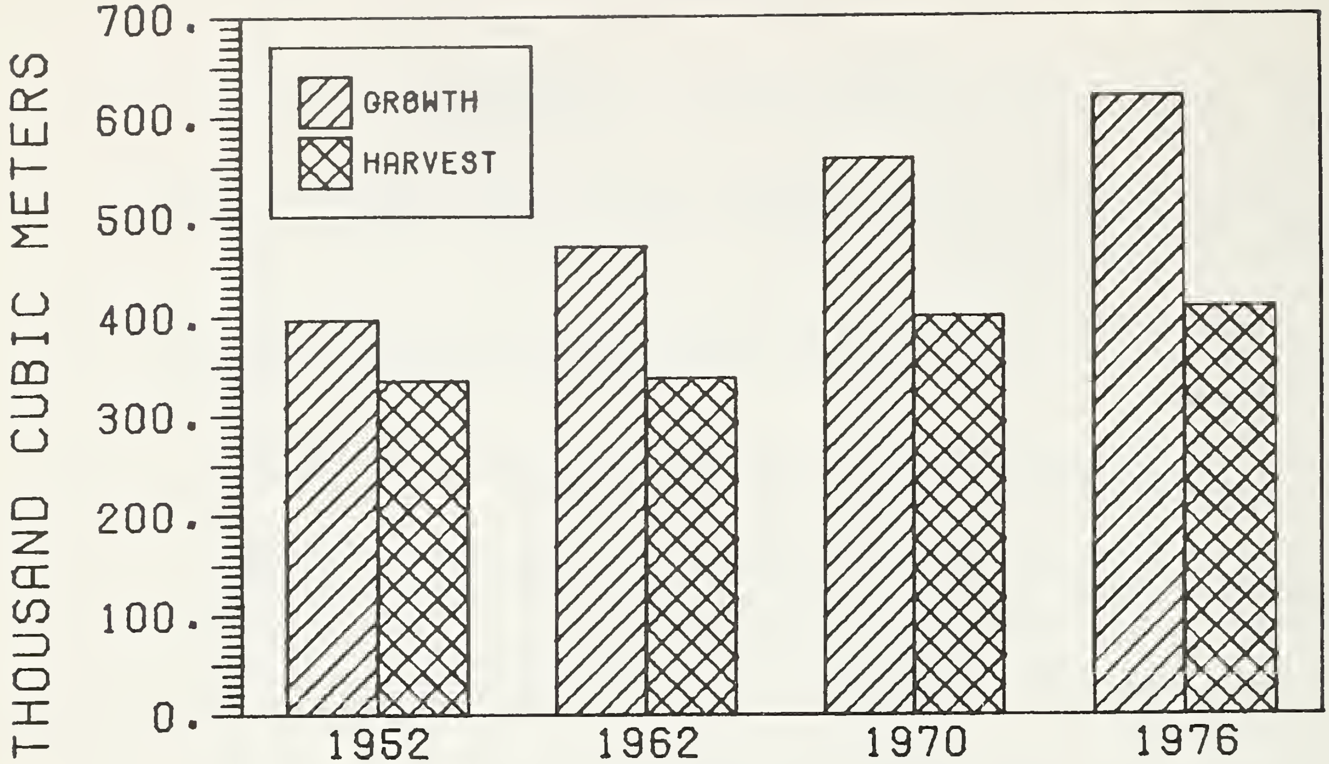

Figure 4.--Net annual timber growth and harvest in the United States, 1952-1976.

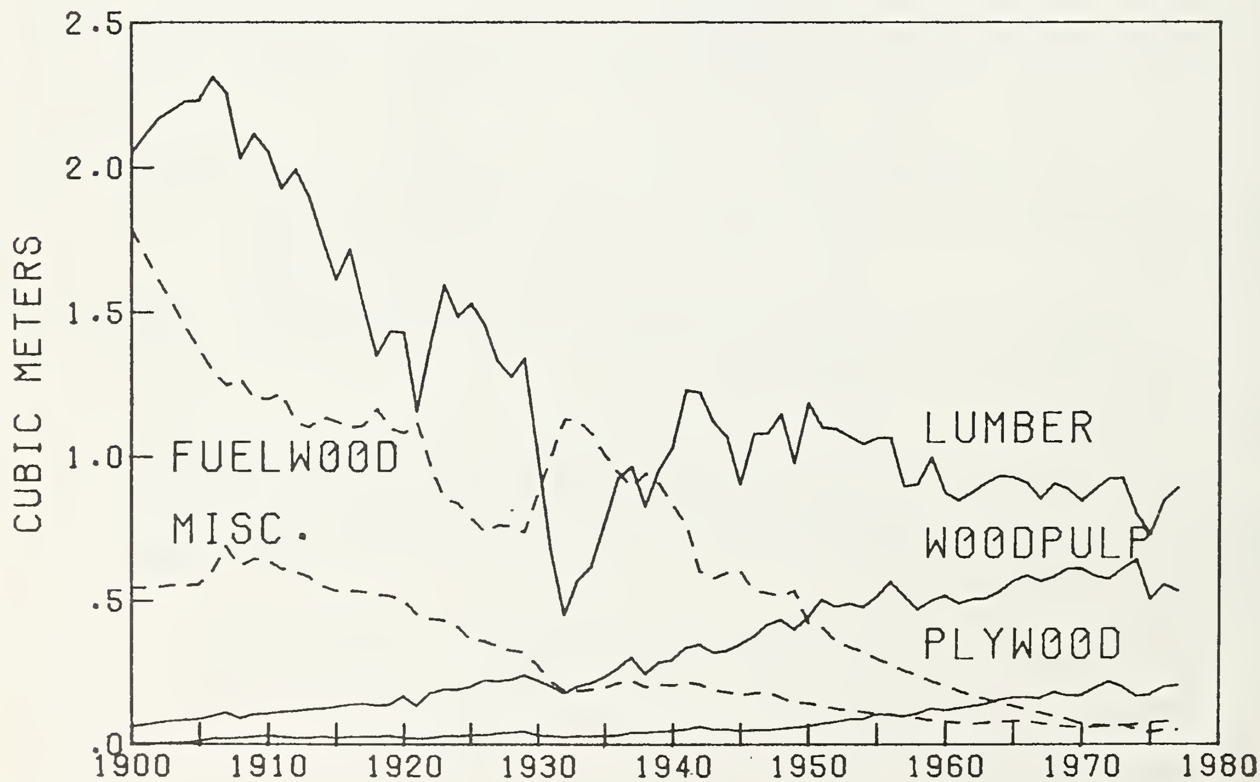

Figure 5.--Per capita roundwood consumption in the United States, 1900-1977.

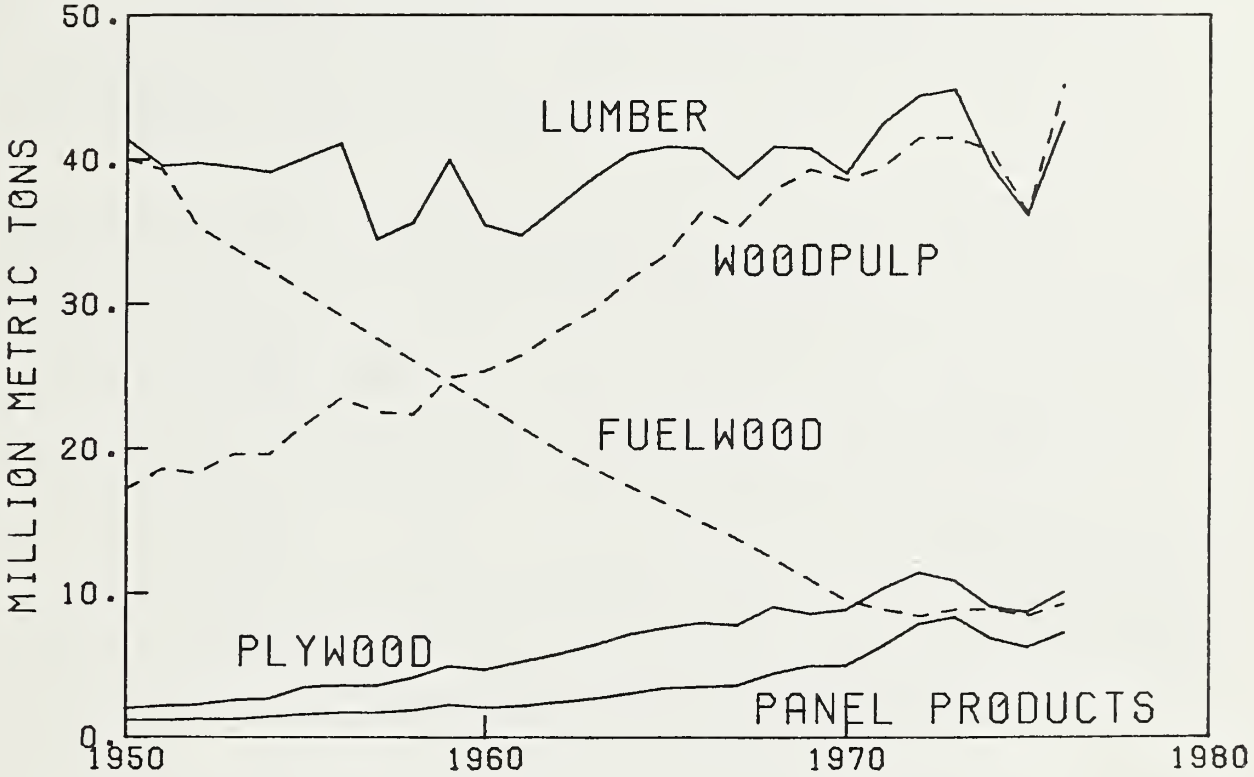

Figure 6.--Wood products consumption in the United States, 1950-1976.

Table 1.--Demand for wood products in the United States in 1976 with projections to 2030

Product	Consumption, 1976	Medium projections of demand	
		2000	2030
LUMBER (BILLION BD. FT.)			
Softwood	36.8	51	56
Hardwood	6.5	12	17
PANEL PRODUCTS (BILLION SQ. FT. 3/8-IN. BASIS)			
Softwood plywood	17.1	27	33
Hardwood plywood	3.6	5.1	6.0
Insulation board	4.5	5.1	5.8
Hardboard	2.1	4.5	7.0
Particleboard	6.3	15.2	24.4
PULP & PAPER (MILLIONS OF SHORT TONS)			
Woodpulp	48	82	126
Paper, paperboard & building board	64	124	195

Wood Utilization Challenges

A. Utilization of less desirable species, sizes, and quality of timber.

There are many opportunities to use hardwoods, low-quality trees, thinnings, improvement cuts, salvage, and residue--and more are in the offing as an outgrowth of research that has been completed and research now in progress. I will cite just a few examples:

Pulp and paper.--Softwoods have long been favored for most types of pulp and paper because of their long fiber, high strength, and well-developed processing methods. Large volumes of desirable softwoods are imported as pulpwood and newsprint from Canada, accounting for a great deal of our net importer status.

But we do not need to depend as much on softwoods for pulp and paper as we have been accustomed to, particularly on softwood cordwood. Figure 7 shows what has been happening to United States pulpwood production over the last quarter century. Production of softwood cordwood for pulp has increased substantially, but the rate has been slowing down in recent years. Production of hardwood cordwood for pulp has been increasing steadily. But the spectacular increase has been in chips--mainly byproducts of sawmills and veneer mills. However, improvements in sawmilling technology and increased use of byproducts for fuels will limit further increase in this source of pulp furnish.

Forest Products Laboratory research many years ago led to the neutral sulfite semichemical pulping process that has been used extensively for pulping hardwoods up to this time. The press drying concept, now being pilot tested at the Laboratory, is designed to greatly expand pulping and papermaking opportunities for hardwoods by improving bonding of fibers and increasing strength; at the same time it also conserves energy.

Flakeboard.--Flakeboard and the more general designation of particleboard indicates another broad area of opportunity for increasing use of less preferred species and sizes. Here we must start with small pieces, so the primary criteria are quality of the particles, cost of gathering the material, processing costs, and performance of the board. Preferred species are not necessary.

We have made floor and roof sheathing boards out of hardwoods and forest residues. These have been made to strength and stiffness specifications of the most common structural class of plywood.

Working with researchers at Purdue University, the Laboratory has also made decking panels out of hardwood residues; these panels show real promise for heavy decking as in built-up industrial and home roofing.

These products are not common on the market yet, because of questions of processing cost and adhesive durability. But our studies show the concepts to be feasible, and we expect to see them soon in use in a

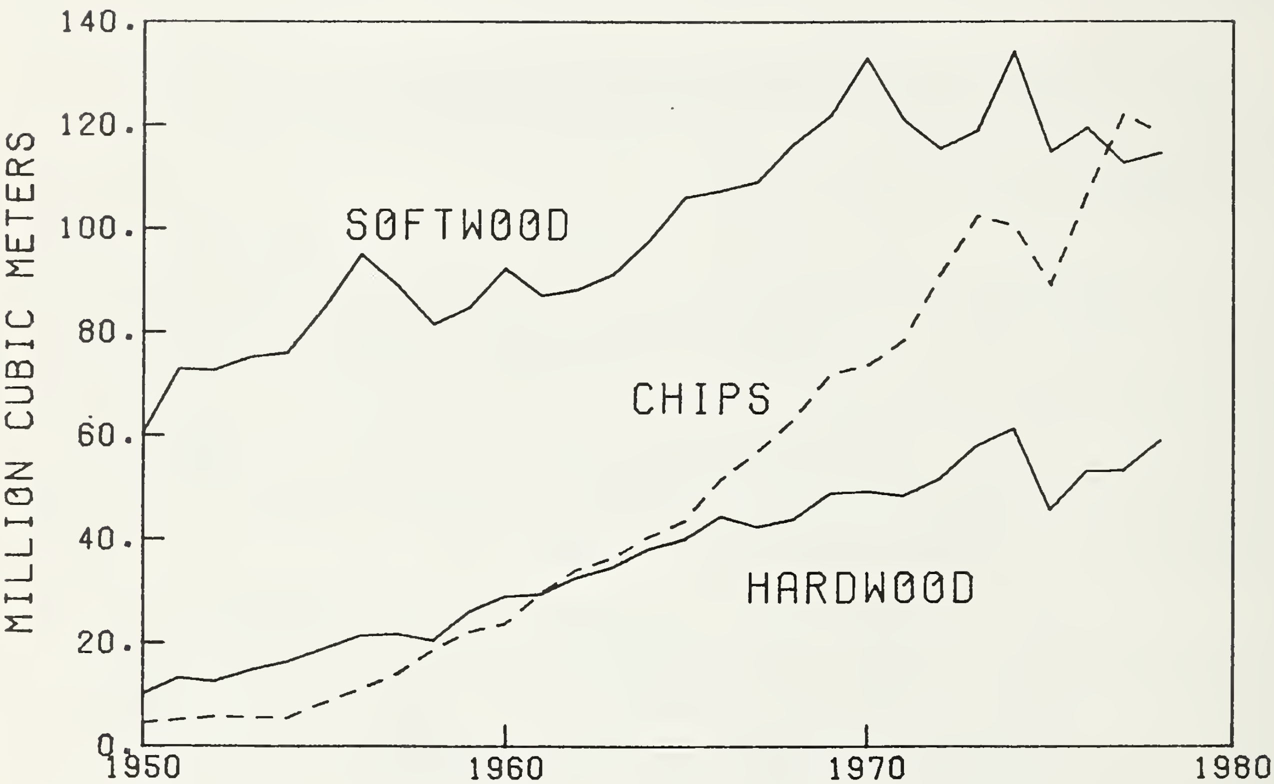

Figure 7.--Pulpwood production in the United States, 1950-1978.

variety of building products that will make use of this "unwanted" portion of the timber resource. Additional research on cost, type, and application of adhesives for both durability and economy will increase acceptance and use of these ideas.

Structural lumber.--Traditionally, softwood of relatively high quality is used for structural lumber. However, a wide variety of hardwoods and lower quality softwoods can be used instead.

The Press-Lam concept, using parallel-laminated thick veneer, can be used to make structural members out of hardwoods that vary greatly in quality, with substantial improvements in strength and durability. This concept has had much attention from the industry and seems to be economically feasible. Press-Lam has already been used to build a highway bridge in Virginia in the George Washington National Forest from oaks that are native to the region.

A more recent concept for producing structural lumber from hardwoods is the "Saw, Dry, and Rip" (SDR) approach. The problem with making solid structural lumber from hardwoods is the pronounced tendency of the lumber to warp during drying. In the SDR approach, logs of "soft" hardwoods are sawed full width into boards, the full-width boards are dried and then ripped to width. We have shown that this simple idea can produce straight studs from yellow-poplar (*Liriodendron tulipifera*), an eastern hardwood species in excess supply. We are presently extending this concept to aspen (*Populus tremuloides*) and red alder (*Alnus rubra*), two other "soft" hardwoods that could be of value in such applications.

Fuelwood.--One might logically think of fuelwood as a major outlet for much of the low quality and otherwise less desirable timber impeding effective management of the Nation's timberlands. It is true that this is a substantial opportunity in some parts of the country, as in northern New England, for example.

However, the fact is that wood already is satisfying more energy needs than most people realize. The opportunities for both conserving energy supplies and providing options for better timber resource management through efficient use of wood are substantial, but more diverse than the public is likely to perceive.

Most people think of fuelwood as the major contribution of forests to U.S. energy requirements. And, until the 1900's this was so. Today, wood is a major energy source only in the forest products industries. Some 20 to 25 million tons, dry basis, of wood and about 10 million tons of bark were burned for fuel in 1976. Two-thirds of this was at forest products plants, and the other third was nearly all used in home fireplaces.

The most important opportunity for increasing the direct supply of energy from forests in the next 10 years is through increased use of low-grade wood and bark in forest industry boilers. Forest industries currently produce 1.1 to 1.6×10^{18} joules (1 to 1.5×10^{15} Btu's) per year from mill residuals. They purchase another 1.6×10^{18} joules. By

increasing the use of mill residues--and in some cases forest residues--it should be possible to reduce the purchased quantity of energy substantially.

After the forest industries, households are the second largest users of fuelwood. But in general, wood appears to be an inconvenient and expensive means of supplying our largely urban population directly with energy. (There are exceptions, such as I have mentioned above.) In 1976, 200,000 households used wood as their primary fuel for cooking and 900,000 as their primary heating fuel. Use as a primary heating fuel has increased slightly in recent years, and we expect this trend to continue. We expect combined use of wood as a residential heating and cooking fuel to rise to about 16 million tons per year by 1990. But this would still be small in comparison to pulpwood consumption (likely to be 125 million tons or so by 1990)--or to total residential energy requirements (which already exceed the energy value of a billion (10^{12}) tons of ovendry wood).

Other energy uses of wood and wood residues are of interest and are being pursued. Notable among these are potential use by steam-electric plants (which consumed 23×10^{18} joules (22×10^{15} Btu) of primary energy resources in 1977), and production of liquid fuels--especially ethanol and methanol--from wood. These may grow in importance in future years and offer new potential for broad use of the resource base of timber and other biomass.

A key element in all energy uses of wood is the cost of delivering a ton of fuel to the point of use. In the case of mill residuals, this cost is relatively low. But, in most areas of the United States, it is at least $25 per dry ton for material harvested specifically for fuel or pulpwood. And the cost increases as transportation distances increase and as concentration of source material decreases. Thus, for larger installations, such as chemical plants or steam-electric utilities requiring thousands of tons daily, costs might well be higher than current pulpwood costs. Research and development to reduce costs of harvesting, transportation, processing, and storage are needed to realize the full potential of wood as a source of energy.

Thus, U.S. forests today contribute an amount of energy for industrial and household use that is minor in terms of National energy consumption--less than 2 percent--but major in terms of forest products industry requirements--nearly half. We expect some increase in energy uses of wood in various sectors of the economy, but most importantly in the forest industries.

Derived fuels and chemicals.--Besides direct combustion of wood, with which I have been dealing, it is possible to convert wood to other solid, liquid, or gaseous fuels. However, as wood is converted to solid or liquid fuel forms, the total potential heat value is substantially reduced due to energy required in processing. Total potential heat value of charcoal is about 50 percent of that of the original wood, that of methanol about 38 percent, and that of oil about 32 percent. The advantage one gains, of course, is in improved capability for transportation, storage, and use of the product. Conversion of wood to a

producer gas that is burned for fuel in a close-coupled operation may result in overall process efficiency of 80 to 90 percent. Methanol can be made much more efficiently from either natural gas or coal than from wood.

Another possibility for an alcohol derived from wood is ethanol produced by either acid hydrolysis or enzymatic processes. In these approaches, cellulose in wood is converted to sugars, then the sugars are fermented to produce alcohol.

Drawing on the other major constituents of wood--hemicelluloses and lignin--ethanol can be co-produced with other chemicals, such as furfural and phenol. Hemicelluloses can be readily converted to furfural, an industrially important chemical that might be used as an adhesive or in other products. Another possibility is to make xylitol, now being used as a sugar substitute, from hemicelluloses. There is still a problem, however, in converting lignin to high-volume, high-value chemicals. Various chemical products, such as vanillin, are derived from lignin, but demand for them is low. Several companies are working on hydrogenation processes in which lignin is cracked to phenols under high pressure in a hydrogen atmosphere. Phenol is an important industrial chemical and a feedstock for manufacturing waterproof wood adhesives. Lignin hydrogenation could develop into an important process for utilizing more wood for chemicals.

It will probably be some time before wood is used extensively as a source of synthetic fuels or petrochemical substitutes in the United States. The situation is considerably different, however, in some developing countries. For instance, Brazil has no indigenous supplies of petroleum. Coal deposits are meager and in remote locations. Brazil does have large supplies of hardwoods, many of which are not used to produce lumber, veneer, or paper. Brazil is actively studying the opportunities to convert such hardwoods to fuels and petrochemical substitutes and may be able to substantially reduce demand for imported petroleum as a result.

B. More effective utilization of forest products already entering the production stream.

My basic premise here is that the most important contribution timber can make to our economy is through efficient production and use of wood as material.

As far as energy is concerned, increased relative dependence on forest products would save an amount of energy that would come at a very high cost if generated from oil or gas. Why do I believe this? Let me explain.

Burning wood, at best, substitutes 1 Btu from wood for 1 Btu from oil, gas, or coal. But when we use wood in place of energy-rich materials--plastics, steel, or aluminum--Btu savings are multiplied. Most forest products are made with small requirements for fossil fuels as compared to substitutes. It takes about 0.2 ton of coal, or equivalent, to process a ton of wood. This is due in part to the happy circumstance I mentioned

earlier--that residues from processing and harvesting can contribute a very large amount of the energy neede for forest products manufacturing. It also comes in part from the relat. ely low energy requirements for processing forest products.

A ton of aluminum, by contrast, requires the equivalent of 10 tons of coal for processing. Steel requires 2 tons, and plastics the equivalent of 6 tons of coal or 10 tons of wood. Thus, it would require a substantial increase in fossil fuels to replace the 60 million tons of lumber and plywood consumed annually in the United States with aluminum and steel--or to replace with plastics our annual consumption of 65 million tons of paper and paperboard.

But, in the U.S. materials economy, wood has been gradually declining in importance as compared to metals, concrete, and plastics. One factor, until now, has been the widespread availability of low-cost energy. With the new situation of higher--and increasing--energy prices, the comparatively low energy requirements of forest products may tip the balance in their favor.

One factor that will enter the picture here is more efficient conversion of logs to lumber. An example is the recent introduction of automated scanning and computer controls in sawmilling. At least 100 mills using computerized sawing and the Best Opening Face concept are increasing yield by 10 percent or more--especially if they are sawing small logs. Another example is edge gluing and ripping to produce wide widths from small logs.

There is still another element of technological improvement to be considered. To a large degree, the competitive position of forest products in our economy depends upon the cost to the businesses and consumers who use these products. To a builder, this means more than cost per unit volume for lumber or for panel products. It means primarily cost per unit volume of building space, considering labor, materials, and other costs. Engineering improvements that allow him to use wood products more efficiently may be just as important as reducing his product manufacturing costs.

An example of innovation in construction engineering is the roof truss--which today is widely used. Also well known is the concept of a floor truss used in place of solid wood floor joists. An engineer at our Laboratory has extrapolated from that idea to the concept of a truss frame. This ties together a floor truss and a roof truss to form a single truss that supports the entire cross section of building, greatly strengthening the house frame, using the wood more efficiently, and reducing the time required for erection.

To the homeowner, durability and ease of maintenance are very large factors. He may prefer aluminum or vinyl siding primarily because he expects not to have to repaint it, while fearing the work and cost of frequently repainting wood siding. But with currently available technology--though too infrequently used--exterior finishes on wood can easily go 10 years or more between paintings.

There is also the problem of developing the technical basis for codes, standards, and design methodology which reflect accurately the true performance requirements and capabilities of varying materials and structural designs. Current wood engineering research is providing a base for improvements in efficient structural use of wood. The improvements can be incorporated into revised standards which will be similar to performance standards used for other building materials.

Thus we see available now and coming over the horizon advances in wood utilization technology that will effectively extend timber and energy supplies. They will provide for use of small stems, low-quality hardwoods, dead trees, and residues, as well as more effective use of high-quality wood of preferred species. They will effectively conserve energy in the processing and use of wood as an engineering and raw material.

(Paper prepared January 1980)